TOXICITY OF SEVERAL NEW ORGANIC INSECTICIDES TO BODY LICE (PEDICULUS HUMANUS CORPORIS DE G.)[1]

By Franklin S. Blanton, Lt. Col.
Medical Service Corps, U. S. Army

Part II—dust tests

Methods used for testing various chemicals mixed with powder carriers:—All promising lousicides located in the beaker tests were tested in powder formulations. The technique was to dissolve the chemical in acetone and then impregnate this solution on the test powder diluent. One gram of powder was then spread on cloth patches approximately $4\frac{7}{8}$ inches square. These patches were cut from winter-weight cotton underwear cloth. The treated patches were placed on paper-covered plywood boards and 25 young adult lice were confined on each patch beneath an inverted petri dish. Mortality counts were made after 24 hours. The lice were kept in direct contact with the treated cloth except for one series of tests in which they were exposed for only 30 minutes and then removed to clean cloths.

Effect of various dusts or diluents on adult body lice:—A series of preliminary tests were conducted to determine the effect of fifteen diluents on adult body lice.

Preliminary work had been done on this phase of testing and very erratic results were sometimes had, when insecticides were used with various diluents.

It was found that there was considerable day to day variation. The results of four tests on different days are given in Table 3. Of the fifteen diluents tested alone, eight showed definite toxicity to lice. Five of the diluents caused an average of over 90 percent mortality, and one, an average of 60 percent. Cohutta talc gave an average of 18 percent mortality, pyrophyllite 22 percent and the remainder were nontoxic. In subsequent tests pyrophyllite gave even greater kills of lice. Pyrophyllite, which was

[1] For first paper of this series, see Jour. N. Y. Ent. Soc. 61: 169–180. 1953.

toxic, Gypsum, Dilroc, Frianite and Walnut Shell Flour, which were non-toxic were chosen for further comparative tests.

Effect of dust combinations with and without chemicals on adult body lice:—Since the preliminary tests showed large differences in toxicity additional tests were made with some that showed little or no toxicity and with some that showed rather high toxicity. Five of these diluents were selected for testing alone, in combinations containing equal parts of two diluents,

TABLE 3. PERCENT OF LOUSE MORTALITY AFTER 24-HOUR EXPOSURES TO VARIOUS DILUENTS CONTAINING NO INSECTICIDE. FOUR REPLICATIONS OF 25 LICE EACH

Diluent	Dates of Treatment				Average
	Jan. 5	Jan. 11	Jan. 12	Jan. 13	
Activated charcoal	100	100	100	100	100
Wood charcoal	100	100	96	100	99
Fossilite	100	100	96	100	99
Fuller's Earth	100	100	100	92	98
Secco Clay[1]	96	100	lice escaped	80	92
Phospho Dust	100	44	0	96	60
Chutta Talc	12	32	16	12	18
Pyrophyllite	20	60	0	8	22
Dilroc	0	16	0	0	4
Frianite M3X	0	8	4	0	3
Control[2]	0	2	4	0	2
Gypsum	0	0	4	0	1
Walnut Shell Flour	0	0	0	4	1
Cocoa Shell	4	0	0	0	1
Bentonite	0	0	0	4	1
Frianite	0	0	0	0	0

[1] Only three tests of 25 lice each.
[2] Eight tests of 25 lice each.

and these diluents with various concentrations of DDT, chlordane and toxaphene. The purpose of these tests was to determine the most suitable range of concentrations for evaluating them in various diluent combinations.

The results of these very preliminary tests are not tabulated. There was considerable variation in individual tests, but in general, chlordane appeared slightly more toxic than DDT or toxaphene. The latter two were about equal in toxicity.

From these tests it was possible to set up a series of tests

using five diluents both alone and in combination with each other, and with various concentrations of three toxicants, DDT, toxaphene and chlordane.

The results in Table 4 (Series A), show that Pyrophyllite

TABLE 4. AVERAGE PERCENT OF LOUSE MORTALITY AFTER 24-HOUR EXPOSURES TO VARIOUS DILUENTS, WITH AND WITHOUT DDT. THREE REPLICATIONS OF 25 LICE EACH

Diluent	Diluent without toxicant	Concentration in parts per million of DDT in dust			
		5000	2500	250	100
Series A					
Pyrophyllite	96	100	100	100	100
Pyrophyllite + Frianite	93	100	100	95	96
Pyrophyllite + Walnut Shell Flour	5	100	100	21	3
Gypsum	1	100	100	81	12
Gypsum + Frianite	7	100	100	73	12
Gypsum + Walnut Shell Flour	7	100	99	4	1
Dilroc	8	100	100	76	41
Dilroc + Frianite	7	100	100	83	49
Dilroc + Walnut Shell Flour	1	100	96	5	1
Frianite	8	100	100	65	63
Walnut Shell Flour	5	93	53	9	3
Control of (6 of 25 lice each)	3				
Series B (Toxaphene)					
Pyrophyllite	100	100	100	100	100
Pyrophyllite + Frianite	91	100	100	100	96
Pyrophyllite + Walnut Shell Flour	15	100	100	12	11
Gypsum	7	100	100	93	25
Gypsum + Frianite	8	100	100	88	23
Gypsum + Walnut Shell Flour	7	100	100	12	13
Dilroc	21	100	100	96	63
Dilroc + Frianite	17	100	100	93	25
Dilroc + Walnut Shell Flour	9	100	100	3	3
Frianite	11	100	99	99	55
Walnut Shell Flour	3	100	95	13	9
Control (6 of 25 lice each)	3				
Series C (Chlordane)					
Pyrophyllite	99	100	100	100	100
Pyrophyllite + Frianite	73	100	100	100	92
Pyrophyllite + Walnut Shell Flour	8	79	63	8	3
Gypsum	4	100	97	80	41
Gypsum + Frianite	1	100	100	83	43
Gypsum + Walnut Shell Flour	0	79	27	1	3
Dilroc	8	100	100	100	75
Dilroc + Frianite	3	100	100	77	27
Dilroc + Walnut Shell Flour	4	68	39	15	3
Frianite	0	.....	.....	.....	.....
Walnut Shell Flour	4	25	5	16	7
Control (6 of 25 lice each)	3				

alone was very toxic to lice, giving an average of 96 percent kill. In combination with DDT it killed 100 percent of the lice at all concentrations. Pyrophyllite and Frianite mixed in equal amounts were also toxic giving an average kill of 93 percent. DDT, when mixed with the Pyrophyllite-Frianite combination was less toxic than when mixed with Pyrophyllite alone. The Pyrophyllite Walnut shell flour mixture was almost non-toxic, giving an average kill of 5 percent. When mixed with DDT it was highly toxic only at concentrations of 5000 and 2500 parts per million. At 250 and 100 parts per million the average kill was 21 and 3 percent respectively.

Gypsum, Dilroc and walnut shell flour, when used alone were non-toxic, and Frianite was only slightly toxic. All diluent combinations with DDT gave 100 percent kill at a concentration of 5000 and 2500 parts per million, except when walnut shell flour was used. At concentrations of 250 and 100 parts per million pyrophyllite was the only dust that gave 100 percent kill. At these concentrations the pyrophyllite-Frianite DDT combinations gave 95 and 96 percent mortality. Although high kills were obtained in some of the treatments, pyrophyllite was shown to be the most practical dust to use with DDT.

The results in Table 4 (Series B) again show that pyrophyllite was very toxic to lice even when used alone. Complete kill was had in all tests where pyrophyllite was used alone. With the combination of pyrophyllite and Frianite there was an average kill of 91 percent. None of the combinations of dust were outstandingly toxic.

Toxaphene, when mixed with dusts gave 100 percent kill in all combinations at a concentration of 5000 parts per million. At 2500 parts per million, Frianite gave an average kill of 99 percent and walnut shell flour 95 percent. At a concentration of 250 parts per million of toxaphene and various dusts the kill was complete with only pyrophyllite and the pyrophyllite-Frianite mixture. The average for all others was almost 90 percent, except for walnut shell flour which failed to show much mortality. At 100 parts per million complete kill was had with pyrophyllite and 96 percent kill with the pyrophyllite-Frianite-Toxaphene mixture. All others gave poor results.

The results in Table 4 (Series C) show that pyrophyllite was again very toxic to lice when used alone or in combination with chlordane. It was quite toxic when used in combination with Frianite without chlordane and very toxic when used with chlordane. Chlordane when mixed with pyrophyllite gave 100 percent kill at all dilutions. With pyrophyllite and Frianite it gave 100 percent kill at 500, 250, and 100 parts per million. It gave 92 percent kill at 50 parts per million. When mixed with walnut shell flour and pyrophyllite, chlordane gave only 79 percent kill at 500 parts per million. At 500 parts per million, chlordane gave 100 percent kill with all dust combinations except when walnut shell flour was used. At 250 parts per million complete kill was had with chlordane and all dust combinations except with gypsum which averaged 97 percent kill and with walnut shell which failed. At 100 parts per million complete kills were had with pyrophyllite, pyrophyllite and Frianite and Dilroc. Unfortunately, there was not enough Frianite of this particular sample to test it in combination with chlordane alone.

In summary, the results with DDT, toxaphene and chlordane, Table 4 (Series A, B, and C) show that pyrophyllite alone caused 96 to 100 percent mortality of lice, and the combination of pyrophyllite and Frianite was also very toxic. Consequently, where these diluents were used no distinction could be made between either the toxicants or the different concentration of each toxicant, as nearly complete to complete kills occurred in all cases.

Gypsum and Dilroc, alone and in combination with Frianite, showed little toxicity to lice, and in most instances, uniform results were obtained for the same concentration of each toxicant, thus permitting some conclusions as to their relative toxicity. This was also true for Frianite alone, which was relatively nontoxic to lice. Results showed that Chlordane was considerably more toxic to lice than DDT and slightly more toxic than toxaphene, at low concentrations of 50, 100, and 250 parts per million.

The presence of walnut-shell flour in the various diluent combinations caused a marked diminution in the effectiveness of each toxicant, except in the highest test concentration. Walnut shell flour also neutralized the toxicity of pyrophyllite.

Effect of freshly mixed chemical contrasted with mixtures aged for approximately one year in sealed brown bottles: A series of sixteen chemicals mixed in gypsum at concentrations of 5000, 500, and 50 parts per million were tested against lice to determine the effect of storage in brown glass bottles. Comparative tests were made with two series of dusts, one of which had been

TABLE 5. AVERAGE PERCENT OF LOUSE MORTALITY AFTER 24-HOUR EXPOSURES ON CLOTH DUSTED WITH OLD AND NEW LOUSE POWDERS FORMULATED IN GYPSUM.[1] THREE REPLICATIONS OF 25 LICE EACH.

Chemical	Parts per million toxicant in indicated dusts					
	5000		500		50	
	Old	New	Old	New	Old	New
Ether, bis (chlorophenyl)	100	100	.....	.....	.....	.....
Phenol, 2-sec-butyl-4,6-dinitro	100	100	2	36	.....	.....
DDT	99	95	88	84	49	29
Pyrethrine with piperonyl butoxide	100	100	100	100	7	12
Ethane, 1,1,1-trichloro-2-(0-chlorophenyl)-2-(*p*-chlorophenyl)-	17	28	9	13	9	7
Ethane, 1,1,1-trichloro-2-2-bis(*p*-fluorophenyl)-	100	99	68	19	12	12
Biphenyl, 4-ethoxy-	92	80	8	8	7	4
Biphenyl, chloro derivative (Aroclor 1232)	48	64	13	12	17	11
Biphenyl, chloro derivative (Aroclor 1248)	16	19	9	5	7	1
Sulfone, chloromethyl *p*-chlorophenyl	92	97	63	17	38	24
Toxaphene	100	99	99	18	16	12
Chlordane	100	100	84	75	7	32
Lindane	100	100	100	100	77	78
Parathion	100	100	100	100	59	84
Heptachlor	100	100	100	99	25	81
Benzenethiol	100	100	47	79	4	8

[1] In nine tests of Gypsum alone there was 4 percent mortality whereas in eighteen tests with untreated cloth there was 2 percent mortality.

stored for approximately one year and the other for only two or three months. The tests were replicated on three different days.

The results of these tests are given in Table 5. At a concentration of 5000 parts per million there were no outstanding differences between the old and new mixtures. At 500 p.p.m., however, the year-old dusts of compounds 1,1,1-trichloro-2,2-bis-(*p*-fluorophenyl) ethane, chloromethyl, *p*-chlorophenyl sulfone,

and toxaphene were markedly more effective than similar dusts that were only two or three months old. The reasons for these differences are not definitely known, but they may have been due to variations in the dust mixtures or in the test insects. The fresh mixtures of thiolbenzene and 2-*sec*-butyl-4,6-dinitrophenol were more effective than the older ones. With the latter, however, the old mixture, even when freshly prepared showed a low toxicity against lice. Other workers at the Orlando laboratory confirmed this observation with flea tests and the difference is, therefore not attributable to aging.

TABLE 6. Average Percent of Louse Mortality after 24-Hour Exposures to Various Chemicals Impregnated on Gypsum. Three Replications of 25 Lice Each.

Chemical	Concentration in parts per million		
	500	50	5
Lindane	100	100	12
Heptachlor	100	97	0.7
Aldrin	100	88	0
Dieldrin	100	71	1
Parathion	100	57	1
Chlordane	100	27	0.8
Benzene hexachloride (12% gamma)	100	47	1
DDT	97	13	1
Toxaphene	95	1	0
Pinene, chlorinated, 68.5% Cl.	92	0	0
Pinene, chlorinated, 68.8% Cl.	88	3	0
Isobornyl sulfone, chlorinated, 63.3% Cl.	87	0	0
Sulfone, isobornyl phenyl chlorinated, 66.1% Cl.	73	8	1

Controls—Three lots of 25 lice each on gypsum—no mortality.
Six lots of 25 lice each on cloth—1 percent mortality.

Minimum concentration of impregnated dusts:—A series of tests were made using three concentrations of fifteen chemicals impregnated on gypsum. A total of 25 lice was used in each test and each test was replicated three or more times.

The results, in Table 6, show that at concentrations of 500 parts per million, DDT gave an average kill of 97 percent. This is about equal to toxaphene with an average of 95 percent and to chlorinated pinene (68.5% Cl.) with an average of 92 percent. DDT at this concentration was superior to chlorinated isobornyl sulfone (63.3% Cl.) with an average kill of 87 per cent; chlorin-

ated isobornyl phenyl sulfone (66.1% Cl.) with 73 percent, and to chlorinated pinene (68.8% Cl.) with 88 percent. DDT was, however, inferior to lindane, technical benzene hexachloride (12% gamma), chlordane, parathion, heptachlor, aldrin, and dieldrin, each of which gave 100 percent mortality at 500 parts per million. At a concentration of 50 parts per million, DDT gave an average kill of 13 percent which was better than some. Lindane was the only chemical that gave 100 percent kill at 50

TABLE 7. AVERAGE PERCENT OF LOUSE MORTALITY AFTER 24-HOUR EXPOSURES TO VARIOUS CONCENTRATIONS OF CHEMICALS IMPREGNATED ON GYPSUM SPREAD ON CLOTH PATCHES. THREE OR MORE REPLICATIONS OF 25 LICE EACH.

Chemical	Concentration in parts per million					
	500	250	125	50	25	12.5
Heptachlor	100	100	100	100	97	38
Dieldrin	100	100	100	100	93	32
Lindane	100	100	100	100	91	23
Parathion	100	100	100	97	83	11
Aldrin	100	100	100	95	87	41
Chlordan	100	100	100	70	11	0.7
Technical Benzene hexachloride (10–12 percent gamma)	100	100	93	63	15	3
Toxaphene	95	12	9	5	1	0
Pinene, chlorinated, 68.8% Cl.	40	0	0	1	0	0
Pinene, chlorinated, 68.5% Cl.	35	4	1	0	1	1
Isobornyl sulfone, chlorinated, 70.5% Cl.	33	7	0	0	0	0
Sulfone, isobornyl phenyl, chlorinated, 66.1% Cl.	27	3	0	1	1	0
DDT	12	3	0	0	1	1

In six lots of 25 lice each there was on cloth alone 0.6 percent dead.
In six lots of 25 lice each on cloth treated with gypsum dust there was 1.3 percent dead.

parts per million, although heptachlor did give an average kill of 97 percent at that dilution. The next concentration, 5 parts per million, gave little or no mortality for any of the chemicals.

Another series of tests, Table 7, was made which employed thirteen of the better chemicals. Six concentrations of each chemical were used and the tests were replicated three to six times. In these tests all chemicals were superior to DDT. Some were only slightly better but some were extremely toxic. At

500 parts per million DDT averaged only twelve percent kill. This is quite a contrast to the average of 97 percent kill for DDT at the same dilution for the treatment made in previous tests. With such variation it is very important to make all comparative tests at the same time. At a concentration of 125 parts per million, six chemicals gave 100 percent kill. The next concentration, 50 parts per million, eliminated three other chemicals from the outstanding group. At 25 parts per million there were only three chemicals that gave kills above 90 percent and at 12.5 parts per million, all chemicals showed little toxicity.

Part III—fumigation tests

Methods used for testing fumigation qualities:—Several methods were devised and tested in an effort to find a reliable technique for testing chemicals as fumigants against adult lice. Chlordane and dieldrin were used in comparing the different techniques. In the first tests a small vial containing the lice was suspended in a larger vial containing a small woolen pad that had been impregnated with a 10,000 p.p.m. (1 percent) acetone solution of the test chemical. The small vial was closed with screen wire or a cotton plug and the larger vial was tightly stoppered. Suspending the lice in small cloth sacks was also tried. Since the vapors might be lighter or heavier than air, tests were run with the larger vials in upright, inverted, and horizontal positions. Other tests were made in which the treated cloth patches were placed in the bottom or top of a pint jar and lice exposed in small open petri dishes placed on the bottom.

Results of fumigation tests:—It was found that the jar method was superior to the other test methods. It was also found that there was little or no difference in louse mortality if the chemical were placed above or below the lice. It was assumed that the jars were too shallow to demonstrate whether the fumigant was heavier or lighter than air. In final tests the fumigant was placed only in the bottom of the jars. With chlordane and dieldrin complete kill was had in all tests. The other three methods tried, vial in vial, vial in vial-screen caps, and cloth envelopes gave kills ranging from 2 to 35 percent.

Additional preliminary tests of the jar method were made

with five compounds known to have some vapor toxicity. Four or five tests of 20 lice each with each chemical showed the following mortality:

CHEMICAL	PERCENTAGE KILL
Technical benzene hexachloride	100
Chlordane	90
Heptachlor	100
Aldrin	99
Dieldrin	67
Control	1

These results indicated that the jar method was an effective qualitative means for measuring the vapor toxicity of compounds. Dieldrin was the least effective of the materials.

The jar method was then used to test 107 of the better contact insecticides to determine their effectiveness as fumigants. These tests were run in pairs, with an impregnated patch in the top of one jar and in the bottom of the other. Only nine of the compounds showed fumigant properties, the data for which are presented in the following table. Seven of the nine materials, Table 8, gave 100 percent kill of lice at the dosage tested. The other two, 1, 2, 3, 4-tetra-hydro-quinaldine and dieldrin failed to give complete kills.

TABLE 8. Percent louse mortality after 24-hour exposures in fumigant chambers. Ten lice in each test.

Chemical	No. of Tests	Position of fumigant in jar	
		Bottom	Top
Ethyl dithiopyrophosphate, tetra-	4	100	100
Aldrin	6	100	100
Heptachlor	6	100	100
Chlordane	8	100	100
Lindane	4	100	100
Technical benzene hexachloride (10–12% gamma isomer)	4	100	100
Acetic acid thiocyanochloroisobornyl ester	1	100	100
Quinaldine, 1,2,3,4-tetra hydro	3	77	96
Dieldrin	3	53	70
Control, acetone treated patch	8	1	1
Untreated patch	8	1	0

Although tests were preliminary, it was clearly demonstrated that these nine chemicals did possess fumigant qualities.

Further tests were made with concentrations of 100, 50, 25, and 12.5 parts per million. The results, Table 9, show that tetra ethyl dithiopyrophosphate, gave respective kills of 100 and 93

TABLE 9. Average percent louse mortality after 24-hour exposures in fumigation chambers. Three or more replications of 10 lice each.

Chemical	Concentrations in parts per million			
	100	50	25	12.5
Ethyl dithiopyrophosphate, tetra	100	93	7	3
Aldrin	83	30	0	0
Heptachlor	80	30	0	3
Chlordane	50	5	0	0
Lindane	27	0	0	0
Dieldrin	17	0	0	0
Acetic acid thiocyano-chloroisbornyl ester	3	0	0	0
Technical benzene hexachloride (10–12% gamma isomer)	3	0	0	0
Quinaldine, 1,2,3,4-tetra hydro-	0	0	0	0
Control Acetone treated patch. No deaths in 6 lots of 10 lice each.				
Untreated patch. One death in 6 lots of 10 lice each.				

percent at concentrations of 100 and 50 p.p.m. At 100 p.p.m. tetra ethyl dithiopyrophosphate, aldrin, heptachlor, chlordane, lindane, dieldrin, acetic acid thiocyano-chloroisobornyl ester, technical benzene hexachloride, and quinaldane 1,2,3,4-tetrahydro all demonstrated fumigant qualities.

DISCUSSIÓN AND CONCLUSIONS

It should be noted that the discussion and conclusions made at this time are based upon this paper and the two preceding papers on the same subject.

This work was designed to explore the field of new organic insecticides and to test the toxicity of these materials to body lice. Whether any of these materials will ever be used as lousicides depends on the need for new lousicides and their toxicity to men. If lice, like flies, mosquitoes and other insects, have

resistant strains or the ability to produce resistant strains to DDT and other insecticides, the present work will have been justified. It is common knowledge that for houseflies and some other insects continuous treatments with DDT will give rise to resistant strains that cannot be killed at normal exposures with DDT. The introduction of another unrelated insecticide has been resorted to in order to control these resistant pests.

Although a few chemicals were found to possess fumigant qualities this was believed to be only a minor factor and at weaker dilutions contributed little if any to louse mortality.

The data show that chemicals impregnated on cloth in acetone solution (beaker tests) are more toxic to lice than when impregnated on a dust. For example, at a concentration of 12.5 parts per million in the beaker tests, aldrin, heptachlor, dieldrin, parathion, lindane, and chlordane gave 86 to 100 percent kills, but when the same chemicals were impregnated on dusts at 12.5 p.p.m. aldrin gave 41, heptachlor 38, dieldrin 32, parathion 11, lindane 23, and chlordane 0.7 percent kill. Some or all of this may be caused by the unavailability of the chemical since some of it is absorbed by the dust particle. In short, it requires a higher concentration of chemical in dust form than when impregnated on cloth to give equal louse mortality.

The beaker method proved to be a rapid and reliable method for evaluating new insecticides against body lice, but as pointed out by Eddy et al (1947a) materials found to be effective in the beaker method would need practical tests to prove which were good lousicides. When tested in powder form, many of these effective materials proved ineffective. By the same test, however, DDT remained effective for months.

SUMMARY

Body lice, *Pediculus humanus corporis* DeG., which are important as vectors of epidemic typhus, trench fever and relapsing fever have been investigated intensively since 1943. Numerous papers on control methods and a few on biology have appeared since Grinnell and Hawes (1943) published their bibliography on lice and man.

Data are presented on the relative toxicity of 106 compounds which were selected as the most toxic of over 10,000 subjected to screening test.

In the beaker tests the 106 which had been found to be 100 percent effective on adult lice for 31 days or more at 10,000 parts per million were further diluted and better chemicals were again tested at still lower concentrations. Only 13 chemicals were found to be worthy of further study.

By dilution methods, DDT was shown to be inferior to the other twelve promising chemicals at a concentration of 100 p.p.m. and at 50 p.p.m. DDT was inferior to eight chemicals. Three chemicals, heptachlor, aldrin, and dieldrin were outstandingly better than DDT, all giving 100 percent kill at concentrations of 6.25 p.p.m. Aldrin gave 100 percent kill at concentrations of 3.125 p.p.m.

For comparison of these three chemicals with DDT the average percent mortality of lice are extracted from Table 2.

Chemical	Concentration, parts per million					
	100	50	25	12.5	6.25	3.125
Aldrin	100	100	100	100	100	100
Heptachlor	100	100	100	100	100	90
Dieldrin	100	100	100	100	100	85
DDT	88	63	15	3	5	0

Durability tests were made with all chemicals at concentrations of 10,000 parts per million. Durability tests with thirteen of the more promising materials were made at concentrations of 50, 25, 12.5, 6.25 and 3.125 p.p.m. At concentrations of 50 p.p.m., DDT gave a 50 percent kill for one day and none thereafter. The remaining twelve at this concentration were still effective after one day of aging. The most durable chemicals, parathion, and dieldrin, gave 100 percent mortality through the eighth and fifth day respectively at a concentration of 12.5 p.p.m.

In comparative tests, both pyrophyllite alone and the combination of pyrophyllite and Frianite were very toxic. Gypsum and Dilroc alone and in combination with Frianite showed little toxicity to lice. At low concentrations of toxicants, walnut shell

flour combined with the diluents that were toxic to lice caused a marked decrease in effectiveness of each toxicant.

In storage tests with sixteen chemicals impregnated on gypsum, heptachlor deteriorated but the others did not.

In dust tests, with gypsum, at concentrations of 500 parts per million, there were twelve chemicals of thirteen tested which were superior to DDT. Several of these, however, were not effective at lower dilutions.

Six of the chemicals tested were outstanding as lousicides. For comparison of these with DDT the average percent mortality of lice are extracted from Table 7.

Chemical	Concentration in parts per million					
	500	250	125	50	25	12.5
Heptachlor	100	100	100	100	97	38
Dieldrin	100	100	100	100	93	32
Lindane	100	100	100	100	91	23
Parathion	100	100	100	97	83	11
Aldrin	100	100	100	95	87	41
Chlordane	100	100	100	70	11	0.7
DDT	12	3	0	0	1	1

Several chemicals demonstrated fumigant qualities. Those that showed fumigant qualities at a concentration of 10,000 parts per million were further diluted and tested again. Six chemicals, ethyl tetradiethiopyrophosphate, aldrin, heptachlor, chlordane, lindane, and dieldrin, at a concentration of 100 p.p.m., gave kills which varied from 100 percent to 17 percent in the order named. At 50 p.p.m., the kill varied from 93 to 0 percent kill. At 25 p.p.m., none of the chemicals showed fumigant action.

LITERATURE CITED

BAYNE-JONES, S. 1943. The United States of America Typhus Commission. Army Med. Bul. No. 68: 4.

———. 1948. Epidemic Typhus in the Mediterranean Area During World War II. Symposium on "Ricksettsial Diseases of Man". Amer. Assoc. Advancement of Science. Washington, D. C. pp. 1–15.

BLANTON, F. S. 1951. The Control of Body Lice on Prisoners of War at U. S. Ports during World War II. Jour. Econ. Ent. 44 (5): 814.

———. 1951a. Typhus Control at Ports in Japan and Korea after World War II. Jour. Econ. Ent. 44 (5): 812.

Bushland, R. C. 1948. Insecticides for the Control of Lice Attacking Man and Animals. 4th. International Congress on Tropical Medicine and Malaria. 1670–1677.

Bushland, R. C., G. W. Eddy, and E. F. Knipling. 1944. Tests with Synergists for Pyrethrum against the Body Louse. Jour. Econ. Ent., 37 (4): 556.

Bushland, R. C., L. C. McAllister, Jr., G. W. Eddy, and H. A. Jones. 1944. DDT for the Control of Human Lice. Jour. Econ. Ent. 37 (1): 126–127.

Bushland, R. C., L. C. McAllister, Jr., H. A. Jones, and G. H. Culpepper. 1945. DDT Powder for the Control of Lice Attacking Man. Jour. Econ. Ent., 38: 210–217.

Bushland, R. C., S. Shecter, H. A. Jones, and E. F. Knipling. 1944. Antioxidants for Pyrethrum Powders. Soap and Sanitary Chemicals, November.

Bushland, R. C., L. C. McAllister, Jr., G. W. Eddy, H. A. Jones, and E. F. Knipling. 1944. Development of a Powder Treatment for the Control of Lice Attacking Man. Jour. Parasitol., 30: 377–387.

Busvine, J. R. 1944. Destruction of Lice in Clothing by Hot and Cold Air. Bull. Ent. Res. 35 (2): 115–125.

———. 1945. Some Pioneer Work on Protection against Body Lice by the Use of Lasting Insecticides. Bull. Ent. Res. 36 (10): 23–32.

———. 1946. The Comparative Toxicity of Various Contact Insecticides to the Louse (*Pediculus humanus* L.) and the Bed-bug (*Cimex lectularius*) Ann. Appl. Bio. 33 (3): 271–279.

Busvine, J. R. and S. Barnes. 1947. Observations on Mortality among Insects Exposed to Dry Films. Bull. Ent. Res. 38 (1): 88–90.

Buxton, P. A. 1945. The Use of the New Insecticide DDT in Relation to the Problems of Tropical Medicine. Trans. Roy. Soc. Trop. Med. Hyg. 38 (5): 367–400.

Canadel Vidal, J. M. 1946. Experienceas & ensayos con un nueva producto insecticida: el dicloro-fenil-triclorocetano (DDT). Rev. Iber. Parasit. 6 (4): 309–342.

Chalke, H. D. 1946. DDT Experiences of its Use during the Italian Campaign. Roy. Soc. Med. Proc. 39: 165.

Chalke, H. D. 1946a. Typhus: Experiences in the Central Mediterranean Force. Brit. Med. Jour. 1: 977.

Cox, H. R. and J. E. Bell. 1940. Epidemic and Endemic Typhus: Protective Value for Guinea Pigs of Vaccine Prepared for Infective Tissues of the Developing Chick Embyro. Pub. Health Rept. Wash. 55: 110.

Craufurd-Benson, H. J. 1946. Naples Typhus Epidemic 1942–1943. (Sic) as Seen by an Entomologist. Brit. Med. Jour. Hyg. 39: 177.

Culpepper, G. H. 1944. The Rearing and Maintenance of a Laboratory Colony of the Body Louse. Amer. Jour. Trop. Med., 24 (5): 327–328.

———. 1946. Rearing Body Lice on Rabbits. (Scientific note.) Jour. Econ. Ent. 39: 660.

———. 1946a. Factors Influencing the Rearing and Maintenance of a Laboratory Colony of the Body Louse. Jour. of Econ. Ent. 39 (4): 472–474.

———. 1948. Rearing and Maintaining a Laboratory Colony of Body Lice on Rabbits. Amer. Jour. Trop. Med. 28 (3): 499–504.

DAVID, W. A. L. 1944. Fumigation as a method of Controlling the Body Louse, *Pediculus humanus corporis* DeGeer. Practical tests. Bull. Ent. Res. 35 (2): 101–112.

DAVIS, W. A., AND C. M. WHEELER. 1944. The Use of Insecticides on Men Artificially Infested with Body Lice. Amer. Jour. Hyg. 39 (2): 163–176.

DAVIS, W. A., F. MALO JUVERA, AND P. H. LORA. 1944. Studies on Louse Control in a Civilian Population. Amer. Jour. Hyg. 39: 177.

EDDY, G. W. 1944. Treatment for Head Lice, Crab Lice and Scabies. War Med. 6: 319–322.

EDDY, GAINES W. 1946. A Combination Treatment for Lice and Scabies. Jour. Investigative Dermatology. 7: 86.

EDDY, GAINES W. 1948. The Treatment of Head Lice with the MYL and DDT Louse Powders and the NBIN Emulsions. Amer. Jour. Hyg. 47 (1): 29–32.

EDDY, G. W. AND N. B. CARSON. 1946. Further Tests of the More Promising Materials against the Body Louse. Jour. Econ. Ent. 39 (6): 763–767.

EDDY, G. W. AND N. B. CARSON. 1947. Effects of DDT on the Body Louse. Jour. Econ. Ent. 39 (6): 759–762.

EDDY, GAINES W. AND N. B. CARSON. 1948. Organic Compounds Tested against Body Louse Eggs. Jour. Econ. Ent. 41: 31–36.

EDDY, G. W., N. B. CARSON, AND R. C. BUSHLAND. 1947. Results of Screening Tests with Materials Evaluated as Insecticides, Miticides and Repellants. Part II, Evaluation of Materials as Lousicides. U. S. Dept. Agr. E-733, 235 pp.

GOODALL, F. L., T. F. GORTON, AND J. V. SUMMERSGILL. 1946. DDT and its Textile Applications. Jour. Soc. Dy. Col. 62: 189–198.

GOMEZ, OZAMIZ, J. M. 1945. El descubrimiento del nueve insecticide 666. Ion. 5, 53: 745–750.

GORDON, JOHN E. 1948. Louse-Borne Typhus in the European Theatre of Operations, U. S. Army, 1945. Symposium on Rickettsial Diseases of Man. Amer. Assoc. Adv. Science., Wash., D. C. pp. 16–27.

GRINNELL, M. E. AND I. L. HAWES. 1943. Bibliography on Lice and Man. Bibliographical Bulletin No. 1, U. S. Dept. Agr. 1–87.

GORKINA, A. N. 1942. Dusts of "K" and "SK" and Diphenylamine as Insecticides. (In Russian) Med. Parasitol. 11 (1–2): 90–91. Moscow (Abstract Rev. Appl. Ent. 32: 5.)

Hansens, E. J. 1944. Humidity in Relation to the Ovicidal Effect of Powders Used against the Body Louse. J. Econ. Ent. 37 (6): 750–755.

Hose, A. 1942. Ueber Entlausung Durch Ameisen sowie "uber die Wirkung der Ameisensaure auf kleiderlause z. parasitenk. 12 (6): 665–667.

Houghton, J. A. 1946. Determination of Halogenated Hydrocarbons in Air. Bull. U. S. Army Med. Dept. 5: 220–222.

Ivanova, H. Z. 1942. The "SK" Preparation and its Use for Louse Control (In Russian) Medical Parasitol. 10 (5–6): 572–576. Moscow. (Abstract in Rev. Appl. Ent. 31: 226–227).

Jones, H. A. and Helen J. Fluno. 1947. DDT-xylene Emulsions for Use against Insects Affecting Man. Jour. Econ. Ent. 39 (6): 735–740.

Jones, H. A., L. C. McAllister, Jr., R. C. Bushland, and E. F. Knipling. 1945. DDT Impregnation of Underwear for Control of Body Lice. Jour. Econ. Ent. 38 (2): 217–222.

Knipling, E. F. 1946. DDT to Control Insects Affecting Man. Jour. Econ. Ent. 39: 360–366.

———. 1948. Insect Control Investigations of the Orlando, Fla., Laboratory during World War II. Smithsonian Report for 1948 No. 3968, pp. 331–348.

Knipling, E. F. and W. K. Dove. 1944. Recent Investigations of Insecticides and Repellents for Armed Forces. Jour. of Econ. Ent. 37 (4): 477–480.

Knipling, E. F., R. C. Bushland, F. H. Babers, G. H. Culpepper, and E. S. Raun. 1948. Evaluation of Selected Insecticides and Drugs as Chemotherapeutic Agents against External Blood Sucking Parasites. Jour. Parasit. 34 (1): 55–70.

Latta, R. 1944. Methyl Bromide Fumigation for the Delousing of Troops. Jour. Econ. Ent. 37 (1): 103.

Latta, R., and A. H. Yeomans. 1943. Methods and Equipment for Fumigation of Clothing Infected with Body Lice. Jour. Econ. Ent. 36 (3): 402–404.

Latta, R., R. H. Richardson, and J. B. Kindler. 1946. Methyl Bromide as a Delousing Agent. Circular No. 745 U. S. Dept. Agri.

MacKenzie, M. D. 1941. Some Practical Considerations in the Control of Louse-borne Typhus Fever in Great Britain in the Light of Experience in Russia, Poland, Romania and China. Proc. R. Soc. Med. 35 (2): 141–156.

Musgrave, A. J. 1946. Tests on Clothing Impregnated with DDT as an Anti-louse Measure. Bull. Ent. Res. 37 (1): 43–56.

Nicolle, G. 1909. Reproduction experimentale du typhus Xanthematique chez le singe. Acad. des Sci. Compt. Rend. 149–157.

Nicolle, C., C. Compte, and E. Conseil. 1909. Transmission esperimental du typhus Xanthematique par le pou du corpe. Acad. des Sci. Compt. Rend. 149–486.

PETRIE, P. W. R. 1949. Epidemic Typhus in Southwestern Arabia. Ameri. Jour. Trop. Med. 29: 501–526.

RICHARDSON, H. H. 1947. Methyl Bromide Delousing, DDT Insecticides, and Rodent Control Problems at New York Port of Embarkation. Bull. U. S. Army Med. Dept. 7 (3): 308–316.

RICKETTS, H. T. 1909. A Micro-organism which Apparently has a Specific Relationship to Rocky Mountain Spotted Fever. A Preliminary Report. Amer. Med. Assoc. Jour. 52: 379.

RICKETTS, H. T. AND R. M. WILDER. 1910. The Typhus Fever of Mexico (Tabardillo). Preliminary Report. Amer. Med. Assoc. Jour. 54: 405.

RICKETTS, H. T. AND R. M. WILDER. 1910a. The Transmission of Typhus Fever of Mexico (Tabardillo) by Means of the Louse *Pediculus vestimenti*. Amer. Med. Assoc. Jour. 54: 1304.

RICKETTS, H. T. AND R. M. WILDER. 1910b. The Etiology of the Typhus Fever (Tabardillo) of Mexico City. A Further Preliminary Report. Amer. Med. Assoc. Jour. 54: 1373.

RICKETTS, H. T. AND R. M. WILDER. 1910c. Further Investigations Regarding the Etiology of Tabardillo, Mexican Typhus Fever. Amer. Med. Assoc. Jour. 55: 309.

SCOVILLE, ADDISON. 1948. Epidemic Typhus Fever in Japan and Korea. Symposium on Rickettsial Diseases of Man. Amer. Assoc. Advancement of Science. Wash., D. C. pp. 28–35.

SERGEANT, ED AND M. BEQUET. 1944. Conclusions pratiques a tirer d'une experience d'espouillage par poudrage insecticide faite a Maison Carree et l'Arba. (Algeria) Arch. Inst. Pasteur Algeric 22 (2): 109–112.

SIMMONS, J. S. 1945. How Magic is DDT. Sat. Evening Post.

SHERRARD, C. C. 1942. Five Fumigants for Disinfestation of Bedding and Clothing; a Comparative Study of Insecticidal Properties. Publ. Health Rep. 57 (2): 753–759.

SLADE, R. 1945. A New British Insecticide. The Gamma Isomer of Benzene Hexachloride. Chem. Trade Jour. 116 (3017): 279–281.

SOBOLEVA, N. I. 1942. The use of "K" Preparation against Pediculosis (In Russian) Med. Parasitol. 10 (5–6): 576–580. Moscow. (Abstract in Rev. Appl. Ent. B. 31: 227–228).

———. 1942a. The Influence of Antipediculin SK on the Vital Functions of Lice. Med. Parasitol. 11 (1–2): 91–93. Moscow (Abstract in Rev. Appl. Ent. B 32: 6).

SOPER, F. L., W. A. DAVIS, F. S. MARKHAM, L. A. RIEHL, AND P. BUCK. 1945. Louse Powder Studies in North Africa (1943) Inst. Pasteur d'Algerie, Arch. 23: 183–223.

STONE, W. S. 1946. The Role of DDT in Controlling Insect-borne Diseases of Man. Amer. Med. Assoc. Jour. 132: 507.

STONE, P. C. AND D. W. LAHUE. 1946. Rapid Vacuum Fumigation of the Body Louse with Methyl Bromide. Jour. Econ. Ent. 39: 581–588.

Stowman, K. 1945. Typhus during the War. United Nations Relief and Rehabilitation Administration Health Division. Epidemiological Information Bul. 1: 289.

Strong, R. P., G. C. Shattuck, H. Zinsser, A. W. Sellards, and C. Hopkins. 1920. Typhus Fever with particular reference to the Serbian Epidemic. Published by the American Red Cross at Harvard Univ. Press.

Walbach, S. B., J. L. Todd, and F. W. Palfrey. 1922. The Etiology and Pathology of Typhus. Published by the League of Red Cross Societies at Harvard Univ. Press.

Wheeler, C. M. 1946. Control of Typhus in Italy 1943–1944 by Use of DDT. Amer. Jour. Hyg. 36: 119.

Zeidler, O. 1874. Verbindungen von chloral mit Bromand and Chlorbenzol. Deut. Chem. Geselli Ber. 7: 1180.

Zinsser, H. 1943. Epidemiology and the Immunity in the Rickettsial Diseases. Virus and Rickettsial Diseases, pp. 872–907. Harvard Univ. Press.

———. 1944. Rats, Lice and History—Little, Brown and Co., Boston, Mass. 301 pp.